The University of Chicago

COUTCHICHING
KASHABOWIE LAKE, ONTARIO

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE PHYSICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY
1938

By
H. S. PERDUE

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ABSTRACT

The rock assemblage of the Kashabowie Lake area, excluding later intrusives, consists of an altered greenstone series (Keewatin) with adjacent meta-sediments. The age relations are in doubt, though the sediments have been shown as Coutchiching on a previously published map (Kenora sheet).[1]

Field work greatly extended the area of known sediments in Ames and Moss townships. The main greenstone sedimentary contact has been redefined and some sediments discovered on the greenstone side of this contact. Detailed studies near Kashabowie show that interfingering of lavas and sediments does not exist, but thin flows are interbedded with the sediments. The main contact is made by a fault. The fault contact makes age relations difficult to determine, but evidence points to upthrust of the south side, suggesting older age for the volcanics. Major structural considerations favor Knife Lake age for the Kashabowie sediments.

INTRODUCTION

This study consists of the extension westward of the mapping of a sedimentary "mica-schist" series in the Kashabowie area and an investigation of the age of this series relative to that of the adjacent Keewatin volcanics. The area mapped is a part of the northern subprovince of the Lake Superior region and is situated in the district of Thunder Bay, Ontario, about 80 miles west of Port Arthur. It includes Ames and Moss townships and adjacent territory. Two field seasons were devoted to the study—the first to a general examination of the whole area while acting as an assistant on a survey party, and the second, at the suggestion of F. J. Pettijohn, who has emphasized the need of detailed studies of "key areas,"[2] to special study of a rectangular strip extending from the southeastern extremity of Kashabowie Lake westward for 7 miles.

The Kashabowie section of the Thunder Bay district was mapped by William McInnes in 1899,[3] and Moss township in 1927 by R. J.

[1] Map 266A, Ontario, Can., Dept. Mines, *Geol. Surv. Canada* (1933).

[2] "Geology of East Bay, Minnitaki Lake, District of Kenora, Ontario," *Jour. Geol.*, Vol. XLIV (1936), p. 341.

[3] "Report on the Geology of the Area Covered by the Seine River and Lake Shebandowan Map-Sheets," *Geol. Surv. Canada Ann. Rept.* (N.S.), Vol. X, Part H (1899).

Watson.[4] McInnes noted that the area contained mica schists and slatelike schists which he mapped as Keewatin. He also stated: "It is interesting to note that this belt followed westerly along its strike passes into the Coutchiching of Rainy Lake."[5]

Subsequent work to the east by T. L. Tanton[6] has subdivided the Keewatin of McInnes into a volcanic series and a sedimentary series; the latter has been described as Coutchiching. This is of special significance because sediments similar to those mapped to the east occur at Kashabowie and have been shown as Coutchiching on the published Kenora sheet.[7] In addition, the presence of an unfaulted contact between the Keewatin lavas and the meta-sedimentary schists at Kashabowie, reported by Tanton in a personal communication to Pettijohn,[8] gave added significance to the area in the light of the "Coutchiching problem."

As the development of the Coutchiching problem has been summarized by E. L. Bruce,[9] P. L. Merritt,[10] and Pettijohn,[11] further historical treatment of it here does not seem necessary.

Two maps are reproduced; the one (Fig. 1), "Geology of Ames and Moss Townships and Vicinity," shows the area mapped during 1936, and the other (Fig. 2), "Geology of a Portion of Kashabowie Lake and Vicinity," portrays the area of special detailed studies in 1937.

STRATIGRAPHIC AND AREAL GEOLOGY

GENERAL DESCRIPTION AND CLASSIFICATION

The pre-Cambrian formations at Kashabowie as shown on the Kenora sheet[12] are given in the accompanying geologic column with

[4] "Huronian Gold Mine, Moss Township, District of Thunder Bay," *Ontario Dept. Mines Ann. Rept.*, Vol. XXXVII, Part IV (1929), pp. 109–27 (sketch map).

[5] *Op. cit.*, p. 43.

[6] "Eastern Part of Matawin Iron Range, Thunder Bay District, Ontario," *Geol. Surv. Canada Summary Rept. 1924*, Part C (1926), pp. 1–27 (map).

[7] *Loc. cit.*

[8] Pettijohn, "Early Pre-Cambrian Geology and Correlational Problems of the Northern Sub-province of the Lake Superior Region," *Bull. Geol. Soc. Amer.*, Vol. XLVIII (1937), p. 159.

[9] "Coutchiching Delta," *Bull. Geol. Soc. Amer.*, Vol. XXXVIII (1927), pp. 771–81.

[10] "Seine-Coutchiching Problem," *Bull. Geol. Soc. Amer.*, Vol. XLV (1934), pp. 333–74.

[11] "Early Pre-Cambrian Geology, etc.," *op. cit.*

[12] *Loc. cit.*

some modifications. The sediments mapped as Coutchiching are regarded by the writer as of questionable age and are accordingly here named Kashabowie sediments. They are known to contain volcanic admixture and therefore are not to be correlated, so far as present information goes, with the Coutchiching series of Rainy Lake described as free from volcanic admixture by A. C. Lawson.[13] As a result of the present study they are provisionally placed stratigraphically above the Keewatin. These sediments may possibly be Knife Lake[14] in age, for they are lithologically similar to the Knife Lake mica schists.

The Keewatin rocks which occupy nearly one-third of the area studied are, in the main, an altered assemblage of volcanics which have been correlated with the Keewatin of the Lake of the Woods region. This correlation has been made by all previous workers within the area and in adjacent areas where similar rocks are found. These greenstones are of "Keewatin type," and their classification as Keewatin is adopted in this study.

The Kashabowie sediments lying to the north of the greenstone series occupy approximately 80 square miles of the area, attaining a maximum width of nearly 8 miles at the western border of the map area. These pre-Cambrian sediments are mainly metamorphosed graywackes, arkoses, and slates. The development of micas and foliation within these rocks has given them a characteristic mica-schist appearance. The original bedding has been well preserved, and the recognition of these rocks as sediments forming a distinct series has not been questioned.

Both the greenstone series and the sedimentary rocks have been intruded by a granite which has been considered to be Algoman in age by Tanton.[15] This correlation is accepted by Leith,[16] and R. T. Chamberlin.[17] The main body of this intrusive is apparently con-

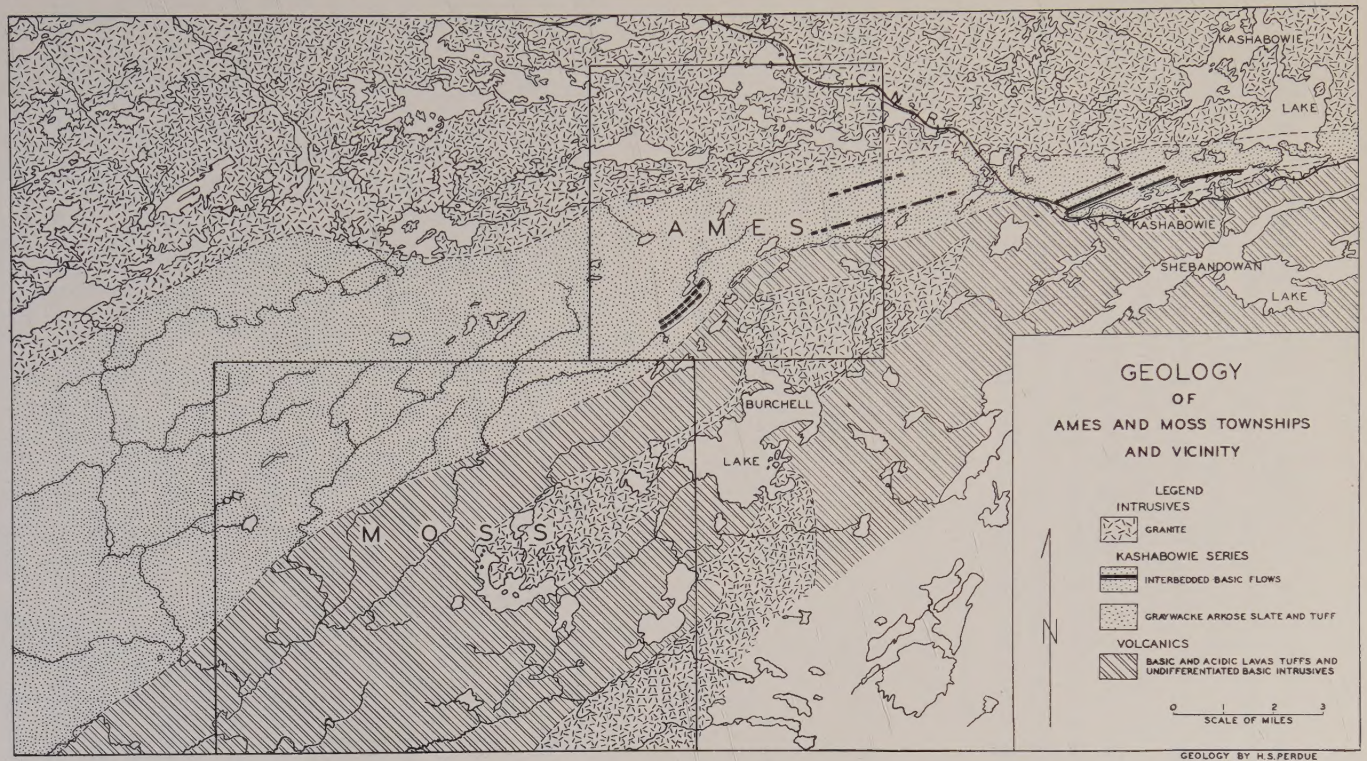
[13] "The Archean Geology of Rainy Lake Re-studied," *Canada Dept. of Mines Geol. Surv. Mem. 40* (1913), p. 5.

[14] The writer here adopts the classification of C. K. Leith, R. J. Lund, and Andrew Leith, "Pre-Cambrian Rocks of the Lake Superior Region," *U.S. Geol. Surv. Prof. Paper 184* (1935).

[15] *Op. cit.*, p. 18c.

[16] Leith, Lund, and Leith, *op. cit.*

[17] "Shifting Orogenic Belts of the Southern Canadian Shield," *Jour. Geol.*, Vol. XLV (1937), pp. 663–81.


KASHABOWIE
LAKE
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SHEBANDOWAN
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BURCHELL
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M O S S
GEOLOGY
OF
AMES AND MOSS TOWNSHIPS
AND VICINITY
LEGEND
INTRUSIVES
GRANITE
KASHABOWIE SERIES
INTERBEDDED BASIC FLOWS
GRAYWACKE ARKOSE SLATE AND TUFF
VOLCANICS
BASIC AND ACIDIC LAVAS TUFFS AND UNDIFFERENTIATED BASIC INTRUSIVES
N
0 1 2 3
SCALE OF MILES
GEOLOGY BY H.S.PERDUE
1936 & 1937

FIG. 1

tiguous with the Vermilion and Giants Range batholiths to the southwest, which are of undisputed Algoman age.

Dike rocks of basic type cut both the Keewatin series and the sedimentary group. Similar dikes were not observed to cut the granite intrusive. The age of these dikes was not determined, but somewhat similar dikes in the Matawin iron range have been regarded tentatively as Keweenawan in age.[18]

The pre-Cambrian units which have been recognized are summarized in the following geologic column:

Keweenawan?	Diabase dikes
Algoman	Granite, syenite, gneiss, and related dikes
Knife Lake?	Graywacke, arkose, slates, paragneisses, small chlorite schist bands, tuffs, volcanic breccia, and interbedded basic flows
Keewatin	Altered lavas, pyroclastics, basic intrusives, iron formation, and some sediments

DESCRIPTION OF THE KEEWATIN ROCKS

The Keewatin greenstones in the Kashabowie region form a broad southern belt which is made up mainly of lavas of acidic, basic, and intermediate rock types together with some intrusives. The term "volcanics" has been generally adopted in descriptions of these rocks because of the extreme difficulty experienced in any attempt to map the intrusives separately from the extrusives, the whole assemblage having been metamorphosed sufficiently to render separation in the field almost impossible. The rocks are mostly andesitic in nature. They weather to varying shades of green, light apple green being characteristic. In the hand specimen they appear gray green and are commonly fine grained. More basic types weather to darker shades of green, whereas the acid rocks vary from gray to what sometimes appears as pale-green to almost white exposures. Ellipsoidal structures, volcanic agglomerates, and amygdule zones are locally common and yield evidence of the effusive character of the bulk of the series. Chlorite and sericite schists are frequently observed. Diorite

[18] Tanton, *op. cit.*, p. 21*c*.

and gabbro intrusives and dark basalts are a part of the series. Some banded iron formation, consisting of magnetic iron-bearing bands interlayered with dark cherty bands, gives probable evidence of sedimentary origin.

A small outcrop of banded graywacke-type sediments exhibiting graded bedding was observed within the greenstones on the south shore of Kashabowie Lake, about thirteen chains west of the crescent-shaped island in the southeast bay (see Fig. 2). As far as could be ascertained, these sediments were within the greenstone series, but no contact was observable.

A quartzite of possible sedimentary origin has been reported within the Keewatin east of Burchell Lake.[19] The writer examined this quartzite and found that the exposures showed a complex of greenstone, quartzite, and sericite schist, which could not be separated from one another except by very detailed mapping. It was concluded that the quartzite showed evidence of being a replacement deposit, this being suggested particularly by its chalcedony-like nature. Moore concluded that it was a quartzite deposited on the Kee-

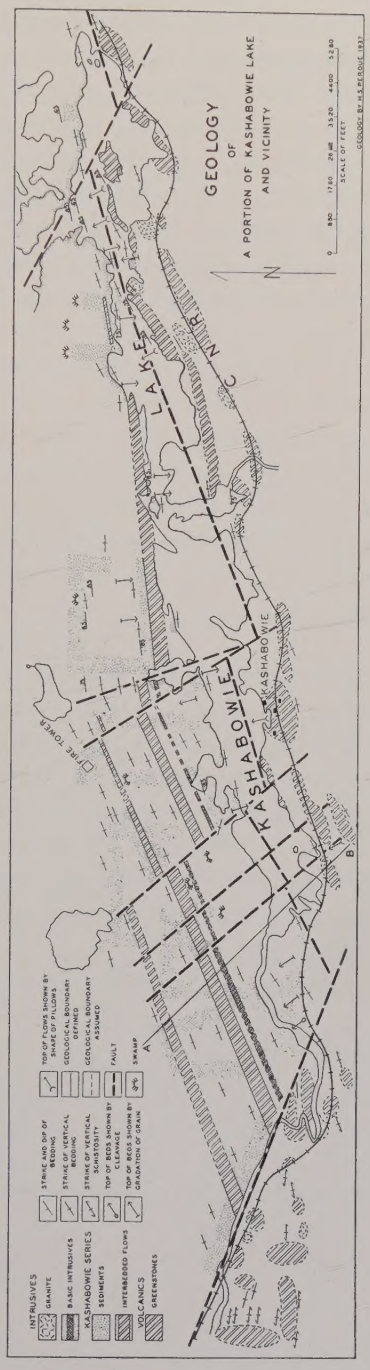

FIG. 2

[19] E. S. Moore, "Geology of Tip Top Mine," *Ontario Bureau Mines Rept. 20*, Part I (1911), pp. 209–13.

watin rocks and infolded. For greater detail the reader is referred to Moore's description.

The metamorphosed greenstones were not subdivided by the writer as had previously been done by Watson,[20] who attempted to divide the series in Moss township into acidic and basic types and mapped them as such. The writer collected suites of samples across the contacts as mapped and found no good basis for the separation. Watson has admitted that "the two types are so frequently intermingled that a decision is very difficult. The map simply indicates the dominant rock type."[21] Watson's descriptions of these Keewatin rocks and Tanton's[22] descriptions of what is believed to be the same series to the east are adequate for general purposes, and the writer cannot materially add to what is already known about the series.

Structural studies show that these Keewatin rocks are isoclinally folded. Their thickness was not determinable, but, even allowing for much repetition due to folding, the original thickness must have been considerable, for the belt has been stated to be about 14 miles wide.[23]

KASHABOWIE SERIES

Distribution.—The Kashabowie series occurs in an irregular wedge-shaped area within the district mapped. These sediments form a belt which is approximately half a mile in width at the eastern border and nearly 8 miles wide at the western border of the map area. The series is bounded on the north by a granite with which there is a gradational contact characterized by lit-par-lit injection gneisses and pegmatitic intrusions. The southern border is the contact with the greenstones from which the Kashabowie series is separated by a fault.

Lithology.—The Kashabowie sedimentary series is largely composed of graywacke-type rocks which are characteristically pale to medium gray in color, commonly weathering to a buff shade. They are mostly very thin bedded, the layers ranging from one thirty-second up to several inches in thickness. What are apparently wider bands are observed in places, but closer inspection usually discloses the smaller units within the larger. The rocks are medium to fine

[20] *Op. cit.*, p. 114.
[21] *Ibid.*
[22] *Op. cit.*, p. 6*c*.
[23] *Ibid.*

grained and exhibit a sandy appearance on weathered surfaces. Alteration has brought about the development of micas which have grown parallel to the bedding planes, causing the rocks to have shiny cleavage surfaces and to be termed "mica schist." The micas are most prominently developed in the sediments in the broad contact zone near the granite and in xenoliths within the batholithic borders. Here the mica is of a darker variety and gives rise to dark-gray and black bands of coarse-grained gneissic material sometimes described as paragneiss. These more pronounced mica schists of the contact zone grade almost imperceptibly into the finer-grained, lighter-colored graywacke-type rocks farther removed from the contact zone.

Thin slaty bands of a dark-gray variety with pronounced slaty cleavage are not uncommon in the assemblage. Megascopically they appear to be a dark fine-grained phase of the typical graywacke, and on good exposures there are graded bedding relationships between the two types.

Chlorite schist beds were occasionally observed interbedded in the graywackes. Bands of this type were called "films" by McInnes,[24] who regarded them as remnants of unassimilated Keewatin. These bands are mostly but a few inches in width, 16 inches being the widest seen. The bands are fairly persistent and vary little in width except where they show pinch and swell phenomena due to dynamic metamorphism. They are regarded as chloritized tuff beds within the series.

On the rocky prominence on which the fire tower is located (Fig. 2), adjacent to the north contact of the northernmost greenstone bed, there is an exposure of fine-grained light-gray tufaceous-appearing rock which occurs in fine bands separated by chertlike layers. Within a zone 4–5 feet in width at this outcrop, there are angular fragments of dark-green basic schist, varying in size from an inch up to as much as 22 inches longest dimension. The fragments were variously oriented with respect to the bedding, and their schistosity was transverse to that of the enclosing material. These fragments are thought to be volcanic bombs interbedded in what is probably tufaceous material.

[24] *Op. cit.*, p. 42.

Further evidence of contemporaneous vulcanism is the presence of flow rocks of dark-green chloritic schist material interbedded with the sediments. These have been found to outcrop within the sedimentary series almost continuously for a distance of nearly 12 miles.

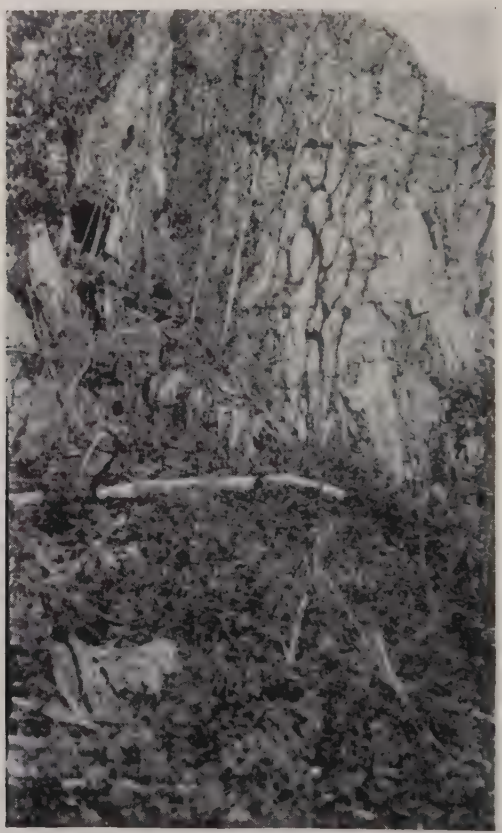

FIG. 3.—An exposure of pillow lavas interbedded with the sedimentary series northwest of Burchell Lake.

One of these bands in the eastern part of Ames township was over a mile from the sedimentary border. These flows were first observed northwest of Burchell Lake, where several outcrops exhibit unmistakable pillow lava structures (see Fig. 3). These pillow structures, unfortunately, were not found to give reliable top and bottom deter-

minations. The writer was, at first, inclined to regard the flows as infolded Keewatin, but evidence to prove their superposition within a syncline was lacking. Top and bottom determinations in the adjacent sediments also were doubtful. Weathering, producing discoloration and other surface changes, was found to have obscured graded bedding relationships. For such determinations the best outcrops are on lake shores, where they are subjected to wave wash, or where uprooting of trees or stripping operations have freshly exposed the bedding.

To the east in the area selected for detailed study the evidence indicated that these flows were interbedded. The broad band which outcrops on the north shore, northeast of Kashabowie village, has several well-exposed contacts with the sediments on its northern border. At these exposures freshly stripped outcrops show graded bedding, which indicates that the top is to the south or toward the greenstone band. The greenstone has a well-defined amygdule zone occurring within a few inches of the sharp conformable contact with the sediments. At places more remote from the contact, pillow lava structures were observable, which together with the unmistakable amygdule zone are proof of the effusive nature of this band of greenstone.

This same band may be traced eastward along the shore until it disappears beneath a prominent drift ridge. It reappears in the next bay to the east, outcropping on the shore just northeast of the small island shown on the map (Fig. 2). The greenstone at this outcrop is separated from the sediments on the south by a small depression. These sediments show graded bedding suggesting top to the south. This is verified by the well-exposed graded bedding on the eastern shore of the small island a few yards to the west. Here the top is clearly to the south (Fig. 4).

The use of graded bedding, i.e., the common occurrence of coarser material at the bottom of each layer grading into finer material above, as an infallible criterion for distinguishing top and bottom of layers has been questioned by Lawson.[25] More recently H. C.

[25] F. F. Grout, "Coutchiching Problem," *Bull. Geol. Soc. Amer.*, Vol. XXXVI (1925); discussion by Andrew C. Lawson, p. 363.

Cooke,[26] has cited evidence of anomalous grain relationships. Such are to be expected, but they are exceptional. In any event, it is now generally accepted by students of the pre-Cambrian that graded bedding in the finer sediments may be used to determine top of the beds when the studies show that this type of bedding is typical of the area and consistently gives determinations which are in accord with conclusions based upon other evidence.

FIG. 4.—The exposure of graded bedding adjacent to the greenstone flow as described in the text. Hammer pick points south. (Photo by F. J. Pettijohn.)

Graded bedding was found to be a reliable criterion in the Kashabowie area. This being so, it is safe to conclude that, since the adjacent steeply dipping sedimentary beds on both sides of the greenstone band have their tops to the south, the greenstone band is interlayered with the sediments. The sediments to the north are older and those to the south are younger than the greenstone flows which do not owe their present position to a synclinal structure such as would naturally be postulated if the sediments were all older than the greenstone schist band.

[26] "Anomalous Grain Relationship in the Caldwell Quartzites of Thedford District, Quebec," *Proc. and Trans. Roy. Soc. Canada*, Vol. XXVII, Sec. IV (3d ser., 1931), pp. 71–74.

Continuing along the north shore eastward from the island, all determinations of a reliable nature consistently indicate top of the sediments to the south. This verifies the other determinations and gives additional proof that the greenstone is interbedded with the sediments. This same flow has been traced westward from its outcrops on the north shore to where it is terminated by a cross fault. This band was not only located by means of transverse traverses but

FIG. 5.—A typical conformable contact between the darker interbedded greenstone and the lighter colored sediments. Hammer head marks contact.

was carefully examined by a longitudinal traverse throughout its length. Both the northern and the southern contacts with the sediments were observed many times and always showed conformable relations (see Fig. 5). Pillow lava structures which, though here unreliable for top-bottom determinations, were good enough to furnish proof of the flow origin of these rocks and were observed at various places throughout most of its length. The results of this longitudinal traverse verify the conclusion that this band constitutes a basic flow interbedded in the sediments. As such it may be used as a horizon marker.

The other occurrences of interbedded basic material were not traced with the same thoroughness as the band just described, but

sufficient traverses were made to delineate them as shown on the map. The more northerly of the bands in the key area is also regarded as effusive. The smaller southern unit is apparently composite in nature, for it displays coarse crystalline texture suggestive of a sill, and yet what appeared to be ellipsoidal flow structures were observed toward its western termination. Since a detailed examination of this band was not essential to this study, no effort was made to map it in detail.

Thickness of the sedimentary series.—The Kashabowie series is isoclinally folded and the details of the structures are too imperfectly known to permit an estimate of the total thickness. A section measured from the fire tower to the north lake shore would apparently give a minimum thickness of 4,000 feet.

Deposition of the Kashabowie sediments.—The outstanding feature of the Kashabowie series is the uniformity of the great bulk of the graywacke rocks. Even in the western portion of the area, where traverses crossed several miles of sedimentary outcrops, a monotonous succession was characteristic. Conglomerates were not observed in the series, nor was any cross-bedding seen. Gradation of grain size from coarse to fine within individual layers was, however, a common feature.

Lawson[27] considered the Coutchiching sediments to have been a basin deposit and the Seine series to be in part, at least, of flood-plain type. Bruce[28] postulated a huge delta of sufficient areal extent to include all the mica schists of northwestern Ontario. But no evidence of the delta type of bedding was observed by the writer. The problem is: How was this enormous bulk of fine Kashabowie sediment deposited under the quiet conditions necessary to produce thin, evenly bedded deposits of the graywacke type? E. B. Bailey[29] has discussed graded bedded sandstones and believes them to be relatively deep-water deposits. He further suggests that there seems to be a connection between graded bedding and geosynclinal depression. C. W. Tyrrell[30] regards the graded bedding type of graywackes

[27] *Op. cit.*, pp. 23 and 62. [28] *Op. cit.*

[29] "Sedimentation in Relation to Tectonics," *Bull. Geol. Soc. Amer.*, Vol. XLVII (1936), pp. 1713–25.

[30] "Greenstones and Graywackes," *Bull. Comm. Geol. de Finlande 102* (1933), pp. 24–26.

as marine or geosynclinal and has emphasized their widespread association with greenstones.

The Kashabowie sediments are mainly of the sandy graded bedding type and probably were deposited in waters deep enough to prevent disturbance of the thin layers. Thus they may have been laid down in a geosynclinal basin.

Correlation of the Kashabowie sediments.—The fact that the Kashabowie sediments contain volcanic admixture may cause some to regard them as a phase of the Keewatin. Lawson[31] has included mica schists within the Keewatin in the type area. The additional fact that the top of the Kashabowie sediments is, in many places, toward the greenstone lends support to such conclusions. However, it will be shown that, where such relations exist, the contact is a fault. Structural relations which will be discussed later suggest that Keewatin lavas are older than the Kashabowie series.

At Kashabowie,[32] and to the east in Goldie township,[33] the sediments have been mapped previously as Coutchiching as a result of Tanton's investigations. Tanton, in accord with Lawson, regards the Coutchiching as free from volcanic admixture, for he states, "This is a mica-schist assemblage and it embraces no lavas where I have mapped it."[34] Therefore, since the Kashabowie sediments do contain volcanic admixture, they cannot be correlated as Coutchiching of pre-Keewatin age.

In Goldie township, where Tanton has mapped the Coutchiching, a conglomerate occurs along the border between the mica schists and the greenstones. According to the description it is part of a series which Tanton has provisionally considered as equivalent to the Windigokan. The series contains a basic conglomerate, arkose, graywacke or tuff, and an iron-bearing slaty formation. The whole series is about 1,600 feet in thickness and is said to be infolded in the Keewatin. The Kashabowie series is lithologically dissimilar, much thicker, and is not infolded in the Keewatin. However, the base of the Kashabowie series is not known; if it were exposed and found to include a basal conglomerate, it might be regarded as a later phase

[31] *Op. cit.*, p. 35.

[32] Kenora sheet, *loc. cit.* [33] Tanton, *op. cit.*

[34] "Stratigraphy of Lake Superior Region," *Bull. Geol. Soc. Amer.*, Vol. XXXVIII (1927), pp. 731–44.

of the Windigokan. Tanton has already mapped the Windigokan as distinct from the mica schists, and the writer accepts his judgment in the matter.

Tanton has suggested that the series provisionally regarded as Windigokan may be equivalent to the Steep Rock series[35] which he has classified with the Seine.[36] Merritt[37] has studied the Steep Rock series and failed to establish Tanton's correlation. More recently Tanton has classified a series in the Mine Centre area[38] containing conglomerate, quartzite, slate, greenstone, and altered sediments as Seine in age. The Kashabowie series, however, has little lithologic similarity to any of these conglomerate-bearing groups. Nor do they strongly resemble the finer clastics of the Seine series as described by Merritt.[39]

It seems, therefore, that the attempt to correlate this series must be carried farther afield—namely, to the Knife Lake slate area. Descriptions of the Knife Lake slates, as presented by Grout,[40] show many features which are common to the Kashabowie series. It is true that the Knife Lake slates have a basal conglomerate and coarse pebbly bands. But, as the conglomerate is patchy in occurrence and the pebbly bands are of minor importance, the absence of these phases in the Kashabowie series does not weigh seriously against correlation. In most respects they are similar. Both series are banded and have graded bedding of the sandy type, containing much graywacke material. Alteration to biotite schists by the granite intrusive is also a feature common to the two series. The broad contact zone characterized by injection gneisses and the biotite-schist inclusions in the granite of the Minnesota area are almost identical with the corresponding features so well developed in the Kashabowie series. In addition, both series occupy a similar position with respect

[35] "Eastern Part of Matawin Iron Range, etc.," *op. cit.*, p. 17*c*.

[36] "Recognition of the Coutchiching near Steep Rock Lake, Ontario," *Trans. Roy. Soc. Canada*, Vol. XX, Sec. IV (1926), p. 48.

[37] *Op. cit.*, p. 360.

[38] "Mine Centre Area," *Canada Dept. of Mines Geol. Surv.* (1936), Map 334A.

[39] *Op. cit.*, p. 347.

[40] "Contact Metamorphism of the Slates of Minnesota by Granite and by Gabbro Magmas," *Bull. Geol. Soc. Amer.*, Vol. XLIV (1933), pp. 989–1040.

to batholiths which may prove to be contiguous. Therefore, it seems to the writer that correlation with the Knife Lake slates appears more probable than with the Windigokan or Seine.

Grout believes that the mica schists of Minnesota and those across the batholith in the Rainy Lake region are continuous.[41] More detailed work may prove that the mica schists of the northern subprovince of the Lake Superior region are all of the same general age and are the time equivalents of the Knife Lake series.

GRANITES

The granitic intrusives and their accompanying pegmatitic injections occur as two types within the Kashabowie area. Those contacting the sedimentary series on the north are part of a huge batholithic mass, whereas the intrusives of granitic nature within the Keewatin are of the boss type. These latter masses were mapped and described by Watson.[42] Careful traversing by the writer showed that the mass north of Burchell Lake is connected with the intrusive southwest of the lake by a narrow neck extending along the west shore of the lake. Watson had mapped these as separate intrusions. The mass north of Burchell Lake was found to be less extensive than previously mapped. Part of the eastern border of the mass southeast of Burchell Lake was obscured by drift and not determined.

These bosslike intrusions show variations from granite to syenite, hornblende-biotite granite being the common type, but locally syenitic phases are evident. The rocks, in the main, display no unusual features, and for further description the reader is referred to Watson's treatment.[43]

The batholithic mass north of the sediments has gradational contact with that series. The contact zone is from 1 to 4 miles in width and is characterized by lit-par-lit granitic and pegmatitic injections into biotite schists. The location of a definite contact was very difficult. If the proportion of granite type rocks predominated, they were mapped as granite; whereas, if the biotite schists made up more than 50 per cent of the observed outcrops, they were included within the sedimentary borders.

[41] "Coutchiching Problem," *op. cit.*, p. 360.

[42] *Op. cit.* [43] *Ibid.*, pp. 116–19.

The present study was not carried beyond the contact zone because the main batholith lay to the north of the area mapped. This same batholithic mass extends to the east, and Tanton[44] has noted that it is a gray biotite granite.

Observations made within the contact zone suggest that the granites of the area present a good field for study. It was noted that all the granitic injections within the Keewatin greenstones were of a pink variety, whereas those in contact with the sediments were commonly gray to white. There appeared to be a change from gray to pink shades farther from the batholithic borders. One very unusual outcrop displayed both the gray and the pink granites with a gradational contact. There was no evidence of two periods of intrusion; no chill zone or change of grain size such as would be expected. Megascopically, the granites were the same except for color. A feature of this exposure was the fact that the gray granite contained biotite-schist inclusions while the pink variety was free from inclusions. Field notes do not show instances of inclusions within the borders of pink granite outcrops. Thus it is apparent that if these observations are typical a problem of assimilation or migmatization may be involved. The scope of the present study did not permit further investigation of this problem.

STRUCTURAL GEOLOGY

FOLDING

As will be evident from a study of the map (Fig. 2) the observed dips of the bedding and the schistosity show the beds to be isoclinally folded and slightly overturned in many places. The strikes of the Kashabowie sedimentary beds in the key area may be grouped into two sets. Those adjacent to and west of the fire tower average about N. 60°–70° E. and those east of the fire tower average N. 70°–80° E. This indicates a change of fold trend in the sediments just north of Kashabowie village.

South of the lake the observed strikes of bedding and schistosity within the greenstones do not display this change of trend, so apparent in the sediments. The strike of the greenstones averages N. 65° E., roughly parallel to the sedimentary trend west of the fire

[44] "Eastern Part of Matawin Iron Range, etc.," *op. cit.*, p. 18*c*.

tower, but at an angle to that to the east. This angular discordance between the two series is increasingly more apparent toward the eastern portion of the lake. It is also very marked $2\frac{1}{2}$ miles west of the village where the greenstones have strikes varying from N. 85° E. to N. 85° W., while the adjacent sediments strike about N. 60°–70° E.

Pillow shapes show the top of the greenstone series to be to the north, indicating the north limb of anticlinal fold in the greenstone facing the sediments to the north. Good exposures on the crescent-shaped island in the southeast bay of the lake exhibit pillow structures which show greatest concentration of amygdules within the north border of the pillows, a dominance of convex curvatures toward the north, and downward-facing pillow points with their apex to the south. All three generally accepted methods of determining top and bottom of flows from ellipsoidal structures are here applicable, and all indicate top to the north.

About thirteen chains west of this island a small patch of sediments on the south shore, apparently interbedded in the Keewatin, has good graded bedding which shows top to the north. Continuing westward the pillow lava zone may be traced discontinuously to beyond Kashabowie village. Evidence wherever deemed sufficiently reliable for safe determination consistently indicated that top lay to the north. Just south of Kashabowie station there are several exposures of pillow lavas where determinations may be made.

North across the lake the sedimentary series, with one exception, shows from observed determinations that top is to the south. Thus the north limb of a synclinal fold in the sediments is opposed to the north limb of the Keewatin anticlinal fold just described.

South of the river and west of the southwest bay of the lake, about fourteen chains west of milepost No. 82, sediments not previously mapped are exposed to the north of the railroad. These sediments have their top to the north. Therefore, a synclinal structure must here exist in the sedimentary series, and this is shown in the cross section (Fig. 6). The south limb of this syncline is not evident farther east because this fold has been truncated by a fault.

It is of significance that the width of the belt of sediments, as measured from the main interbedded flow to the greenstones on the south, varies considerably. One mile west of Kashabowie village the

width is at least 2,600 feet. Twenty chains northwest of the village the width has decreased to about 2,100 feet. About 2 miles farther east the belt has narrowed to only 600 feet. This can only be explained by regarding the contact between the two series to be at an angle to the bedding. The differences in the fold trends of the two series and the evident truncation of the sedimentary group, together with the additional important fact that the tops of the two series are often opposed adjacent to the contact, indicate a transgressive contact.

FIG. 6.—Cross section *A–B* (location shown on Fig. 2)

FAULTING

Boundary fault.—The unconformable relation existing between the Kashabowie sediments and the adjacent greenstones may be satisfactorily explained only on the basis of a fault contact. Such a fault has been shown on the map (Fig. 2). It is located for the most part in the lake bed and is nowhere observable. It is significant that studies to the west of the key area showed that similar conditions prevail there. Everywhere the sedimentary Keewatin contact occupies a depression. For a distance of 14 miles the writer has carefully traversed this contact and found it to occupy lakes, rivers, swamps, or drift-filled depressions. In places the two formations were exposed on opposite sides of a depression only a few yards in width. While the fact that the contact occupies a depression is not in itself proof of faulting, it becomes significant in the light of the discordant relations indicated by the studies in the key area.

The writer believes that this fault is very much longer than the 14 miles thus far recognized. Throughout the length studied, evidence of dip of the schistosity indicates that the fault plane in most places is essentially vertical.

Cross faults.—A large cross fault which offsets the boundary fault is located in the western portion of the key area. The amount of strike slip is over a mile as estimated from the displacement of the Keewatin sedimentary contact (see Fig. 1). The offset indicates a relative movement of the southern side to the northwest. In the key area this fault has a very prominent scarp on its northern side, especially along that portion following the river. Where the fault continues eastward in a straight line it forms a depression with a less pronounced northern scarp until it crosses the stream and is lost beneath the extensive moraine deposits in that portion of the area.

This fault is clearly younger than the greenstones and the sediments and the contact fault, but its age with respect to the granite was not determined. The gradational nature of the granite sedimentary contact rendered evidence of displacement of that boundary difficult to recognize.

It was noted by McInnes[45] that a fault which was in evidence at Baril Bay to the northwest seemed to agree in strike and displacement with one on Greenwater Lake to the southeast of the area studied by the writer. This fault would then be some 20–30 miles in length and should cross the writer's field of study about where the cross fault has been mapped. Merritt has since visited the Baril Bay area and has named the fault the "Baril Bay Fault."[46] He has estimated the displacement to be more than a mile. The direction of offset and the displacement agree with those of the fault described by the writer.

Minor cross faults.—Roughly paralleling the major cross fault are five smaller cross faults mapped in the key area. In each the direction of movement coincides with that of the major cross fault, i.e., the west side moved northward relative to the east side. A sixth fault is postulated in the eastern part of the key area to account for the displacement of the sedimentary greenstone contact so evident there. The five known and the one assumed fault have a total mini-

[45] *Op. cit.*, p. 32. [46] *Op. cit.*, p. 371.

mum strike slip of 1,100 feet. These, together with the major cross fault, would give a total slip of about 9,000 feet. The minor cross faults are not definitely known to displace the Keewatin, but there is every reason to think that they do unless the boundary fault has a very irregular strike where it crosses the key area.

These minor cross faults are typical of more than the key area, for similar ones were mapped northwest of Burchell Lake. There the tracing of interbedded flows in the sediments showed the existence of seven cross faults in a mile. The movement was in the same relative direction as along those of the key area.

In addition to the faults of sufficient magnitude to show on the map, there are innumerable smaller cross faults evidenced on outcrops throughout the entire sedimentary belt. These smaller faults have strikes which average 30°–40° east of south. Displacement is like that observed on the other cross faults, the west side being displaced northward a few inches or feet with respect to the east side.

INTERPRETATION OF FAULT STRUCTURES

It is apparent that the cross faults are all related, for their displacements are all in the same relative direction and their strikes roughly parallel, though in the key area there is some suggestion of a divergence in strike. This divergent pattern becomes more pronounced if the faults of the key area are grouped with those observed northwest of Burchell Lake, where the strike of the fault planes is nearly east-west. These cross faults were apparently due to tension such as would develop from the shove of an arcuate Keewatin block against the sedimentary unit. The diverging trend of cross faults recalls the familiar pattern of tear-faulting strikingly displayed in the Jura Mountains[47] where outward thrusting from the Alpine arc has produced numerous diverging transverse flaws. In the Savant Lake region of Ontario, Rittenhouse[48] found cross faults displacing a major strike fault in a manner very similar to those of the Kashabowie area.

The boundary fault which separates the Keewatin from the sedi-

[47] Albert Heim, *Geologie der Schweiz;* see illustration in *Jour. Geol.*, Vol. XXXVI (1928), p. 537.

[48] Gordon Rittenhouse, "Geology of a Portion of Savant Lake Area, Ontario," *Jour. Geol.*, Vol. XLIV (1936), pp. 451–78.

mentary series does not show any evidence of horizontal movement. No drag in the bedding adjacent to the fault was observed, but the fact that the fault plane truncates the folds is suggestive of at least some horizontal movement. So far as could be ascertained, the fault plane is essentially vertical. Analysis of structures involved points to upthrust of the south side. The cross section (Fig. 6) shows the north limb of a Keewatin anticline apparently thrust upward with respect to the sedimentary syncline on the other side of the fault plane. This is suggestive of a high-angle break-thrust type of fault. To suppose the syncline thrust upward with respect to the opposing anticlinal limb is not in accordance with the accepted ideas of thrusting. To give further support to the suggestion that the south block has been upthrust are the crude mullion structures exposed on the north shore of the southeast bay of Kashabowie Lake. Here the rocks show slickensided and sheared surfaces which dip to the southeast. Furthermore, the majority of recorded dips are to the north, and, although the departure from the vertical is small, it does favor upthrust of the south side. The evidence just cited to show upthrust of the south side is not conclusive, and it might be taken to indicate a normal fault dipping to the southeast. The normal-fault interpretation is not favored because it involves tension forces which do not harmonize with the forces which produced the cross faults.

This boundary fault roughly parallels the Sapawe Lake fault described by J. E. Hawley,[49] and the direction of inferred movement is almost the same, though Gill[50] and Merritt[51] have questioned Hawley's interpretation of the fault movement. In general, the Kashabowie type of faulting is not very different from that encountered in various other areas of the pre-Cambrian shield.

In the Kashabowie area the active displacements which produced the boundary fault and the cross faults offsetting it are regarded as having come from the south. While there may have been two periods of faulting, this is not necessarily required. It is suggested that pressures from the south could have thrust the Keewatin block

[49] "'Seine' or 'Coutchiching,'" *Jour. Geol.*, Vol. XXXVIII (1930), pp. 521–47.

[50] J. E. Gill and J. E. Hawley, "'Seine' or 'Coutchiching'" (discussion), *Jour. Geol.*, Vol. XXXIX (1931), pp. 655–69.

[51] *Op. cit.*, p. 364.

against the sediments to the north which are in a slightly arcuate belt convex on the north. The result of this thrust may have been the creation of longitudinal tension in the curving sedimentary block. This tension would be greater with a steep fault plane such as probably existed. The sedimentary block, in the Kashabowie area, as it was bent around the blunt nose of the northward-thrusting Keewatin, fractured under this tension, producing the cross faults so common to the area. These cross faults probably extended into the Keewatin block, since that advancing unit would shove into the gaps along the sedimentary border developing as a result of the relief when the tension breaks occurred. Thus one period deformation may account both for the boundary fault and for the cross faults.

BEARING OF STRUCTURE ON THE AGE RELATIONS OF THE KEEWATIN AND THE KASHABOWIE SERIES

The structures described in the Kashabowie area show conclusively that the Kashabowie sediments are not overlain conformably by the Keewatin series. Since the contact has been shown to be a faulted one, the relative ages of these two series is not determinable at this place. On the assumption that the upthrust side is eroded more than the downthrow side, it is natural to suppose that the rocks exposed on the upthrow side are the older. The writer questions the validity of such an assumption for the isoclinally folded rocks exposed on either side of the high-angle boundary fault in the Kashabowie area. The depth to which the nearly vertical folded rocks of both the Keewatin and Kashabowie series extended is not known, but was probably many thousands of feet, since both series were doubtless of considerable thickness prior to isoclinal folding which would increase the relative thickness. Even assuming great vertical displacement and considerable erosion of the upthrust side to account for the exposure of deeply buried rocks, there is no necessity for the conclusion that the rocks thus exposed are older than those which have been eroded. They may be the continuation of the same beds.

Little is known concerning the basement relations of isoclinally folded rocks. Cooke[52] has estimated a removal of from 14,000 to

[52] "Kenogami, Round and Larder Lake Areas, Timiskaming District, Ontario," *Canada Dept. of Mines Geol. Surv. Mem. 131* (1931).

31,000 feet of steeply folded rocks, and yet the beds now exposed still dip isoclinally and extend to unknown depths. In the Kashabowie area the depth to which the isoclinally folded sediments and greenstones extended, the amount of upthrust, and the thickness removed by erosion are not known and are at present incalculable. Therefore, it is doubtful if any fair conclusions as to the relative age of the two series can be drawn from the inferred direction of thrust on the boundary fault. There is, however, some reason to conclude that the older, stronger unit would be the upthrust block, but even this criterion would have to be applied with caution.

It is to be expected that an area which has probably undergone two periods of orogeny and two erosive intervals should have a complex structure which can only be unraveled with difficulty. Chamberlin[53] has presented a thought-provoking summary of the orogenic history of the southern Canadian Shield. Upon the basis of his general synthesis the Kashabowie sediments would be expected to be of post-Laurentian age and equivalent to the Knife Lake slates of similar genesis. This is also in accord with the structural relations suggested by Pettijohn,[54] who has postulated some of the pre-Cambrian basins of deposition within the northern subprovince of the Lake Superior region. Pettijohn has outlined a southern basin, the northern border of which extends from the Rainy Lake area eastward through Shoal Lake area, Steep Rock Lake district, Sapawe Lake area, and probably extends to the Block Creek area. The southern border extends northwest from the Vermilion district of Minnesota to the Matawin iron range area in Ontario. Along the northern border of this postulated basin conglomerates have been reported[55] at Rat Root Bay, Neil Point, Cliff Lake, Shoal Lake, Pike Lake, Perch Lake, Jackfish Lake, Atikokan River, and Block Creek. These conglomerates lie between the mica schists to the south and the adjacent greenstones on the north. Along the southern border similar features seem to be indicated, though the mapping in this section has not been so complete. Conglomerates are known to occur in the Vermilion district at the contact of the mica schists and the greenstones to the south. What may be similar conglomerates have

[53] *Op. cit.*

[54] "Early Pre-Cambrian Geology, etc.," *op. cit.*, p. 156.

[55] Merritt, *op. cit.*

been mapped to the northeast in Goldie township, where they also occur between the mica schists and the greenstones to the south. Within this roughly elliptical mica-schist belt is a granite intrusion.

The general picture is that of a granitic mass bordered by mica schists, which are in turn bordered by greenstones with conglomerates between the two series at many places. The granite is considered to be Algoman in age. The mica schists and the greenstones of the northern and southern borders of this postulated basin are lithologically similar. Faulted contact between the greenstones and the sediments has been identified on the northern border in the Sapawe Lake area.[56] Roughly paralleling this fault is the boundary fault on the southern border at Kashabowie—a fault which may prove to be much more extensive than at present mapped.

The relations around this postulated basin of deposition are very suggestive. One readily visualizes the highlands bordering the area and the deposition of conglomerates at the base while the finer sediments were laid down in deeper waters. That the conglomerates are not more extensive in the relatively few areas studied around the borders of this basin may be due to faulting, erosion, original discontinuous deposition, and to concealment beneath drift-covered areas. Detailed work in the many areas yet to be studied will doubtless further our understanding of the problem.

The attempt to correlate the various mica schists on the basis of the location of the sites of deposition seems at the present stage of investigation more promising than attempts to correlate isolated areas of these sediments with greenstones which may be of differing ages. In some areas two periods of vulcanism have been reported in the "Keewatin."[57] The prevailing near-vertical bedding of the mica schists and the greenstones, coupled with fault relations, further complicates age determinations.

The writer has every reason to believe that further work will extend the belt of Kashabowie sediments much farther to the southwest. The trend is definitely toward the Knife Lake slate areas, and the results of further work may establish connection. Until more work is done, one may conclude that the lithologic similarities and

[56] Hawley, *op. cit.*

[57] Pettijohn, "Geology of East Bay, etc.," *op. cit.;* Rittenhouse, *op. cit.*

the broader structural relations are very suggestive of a common age for the mica schists of the Kashabowie area and those of the Vermilion district; they may be part of one great basin deposit of Knife Lake age.

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